PATENT SPECIFICATION 899,606

DRAWINGS ATTACHED.

Date of Application and filing Complete Specification: Oct. 21, 1958. No. 33632/58.

Application made in Canada (No. 738,982) on Oct. 24, 1957.

Complete Specification Published: June 27, 1962.

Index at Acceptance:—**Class 37**, A18(A2: B1B2).

International Classification:—H05d.

COMPLETE SPECIFICATION.

Electromagnetic Prospecting Apparatus.

We, THE INTERNATIONAL NICKEL COMPANY OF CANADA LIMITED, a Canadian Company, of Copper Cliff, Province of Ontario, Canada, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method and apparatus for detecting and measuring mineral ore bodies by mobile operations and, more particularly, to an improved electromagnetic method and equipment for detecting and measuring mineral ore bodies by airborne operations.

Various electromagnetic methods have been used to detect and measure mineral ore bodies by airborne operations. Certain of these prior systems and methods employed a bird towed by a fixed wing aircraft, which bird contained the receiver apparatus while the co-operating transmitter apparatus was located in the aircraft. Such a system requires that the aircraft shall maintain a relatively high altitude, which altitude diminishes the resolving power of the equipment that locates the ore bodies. Further, in the instance of a bird towed by an aircraft, the bird undergoes certain motion relative to the aircraft due to various disturbances, such as air turbulence and variations in the speed of the aircraft. This motion of the bird relative to the aircraft changes the relative position of the receiver coils to the transmitter coils which may cause the receiver coils to register responses from other than conductive bodies, and these responses may be confusingly similar to those that would be expected from a conductive body. Accordingly, in prior systems errors were introduced in the measurements by the motion of the coils in the bird with respect to the coils in the aircraft.

[*Price 4s. 6d.*]

Additionally, under certain terrain conditions using fixed wing aircraft, it is not possible to maintain a fixed altitude above the ground. For example, in mountainous regions where the slope of the ground is greater than the climbing ability of the aircraft it is necessary to increase altitude before reaching a hill and the intervening region is missed because the aircraft is too high.

Improved accuracy and full coverage may be achieved by the use of a unitary structure which contains both the transmitter coils and the receiver coils. These coils are rigidly mounted within the unitary structure, which structure is adapted to be suspended from an aircraft which may be a relatively slow moving or hovering aircraft, such as a helicopter, or it may be attached to a vehicle moving on land or frozen terrain, or on or in water.

According to this invention we provide a method of making a record of responses received from earth formations detected and measured by airborne electromagnetic operations which comprises radiating two electromagnetic fields from a transmitting coil system carried by a bird which is towed from an aircraft by one or more cables, receiving the electromagnetic field responses due to earth formations by a receiving coil system in the bird, impressing the received response on an electrical carrier wave, transmitting the modulated electrical carrier wave along the or one of the cables, detecting and separating the responses due to earth formations from the electrical carrier wave, so that the earth formations are indicated and measured.

Also according to this invention an electromagnetic device for detecting and measuring an ore body comprises, in combination with an aircraft and a bird sus-

pended beneath the aircraft, two transmitting coils carried by the bird, a first and a second power source carried by the helicopter and each tuned to a different frequency and each connected to a separate one of the transmitting coils and a modulator located in the bird and connected to the first and second receivers, two receiving coils carried by the bird spaced from the transmitting coils and each tuned to a different one of the frequencies, and means for receiving and comparing the signals received by the receiving coils. Preferably the transmitting coils are rigidly mounted and oriented perpendicular to each other, one of the receiving coils is in substantially the same plane as one of the transmitting coils and the other of the receiving coils is in a plane substantially parallel to the plane of the other transmitting coil. The means for receiving and comparing the received signals include a first amplifier connected to one of the receiving coils and a second amplifier connected to the other receiving coil. The bird may be an elongated rigid structure, and the bird and the aircraft may be joined by cables wound onto cable drums in the aircraft, thus enabling the bird to be raised or lowered or tilted in relation to the aircraft.

The method and apparatus according to the invention will now be described more fully with reference to the accompanying drawings in which:—

Figure 1 is a diagrammatical perspective view of the construction; and

Figure 2 shows the same construction in block form and includes a longitudinal sectioned view of the bird.

Figure 1 shows in diagrammatical form a helicopter 10, having suspended therefrom a rigid structure 12, which may be called a bird. The bird is suspended from the helicopter by means of supporting cables 14 and 16 in such a manner that the bird maintains a fixed position relative to the aircraft. As shown in Figure 1, the bird 12 is suspended from the aircraft by cables 14 and 16 attached to the bird at points 17 and 18 at or near the ends of the bird. This prevents rotation of the bird with respect to the aircraft. The prevention of rotation of the bird is facilitated by separating the points of attachment to the two cables 14 and 16 to the craft. As shown in Figure 1, the cables 14 and 16 are attached to means for raising and lowering the bird with respect to the aircraft. These means comprise cable winding and unwinding drums 19 and 20 located within the aircraft, the drum 19 being shown to the rear of the forward landing wheels 21 of the aircraft and the drum 20 being shown behind the rearward landing wheels 22 of the aircraft. It is, of course, to be understood that other slow moving aircraft, such as dirigibles, might be employed instead of the kind shown. It is also to be understood that the bird 12 is represented as a simple rigid structure without guiding surfaces such as rudders; however, such guiding surfaces, or other configurations or shapes of birds, may be employed. The spacing of the single elongated bird 12 from the aircraft is dependent on safe flight characteristics of the system and, of course, involves consideration of the size of the bird and the type of the helicopter or other aircraft employed. The bird will normally be less than fifty feet from the aircraft and usually between ten and twenty-five feet from it.

Figure 2 shows in block form a helicopter 10 containing a pair of power sources T_1 and T_2, a recorder 24, and a detector 26. The bird 12, which is shown in section, contains a pair of transmitter coils 28 and 30 oriented substantially perpendicularly or orthogonally with respect to each other. The coil 28 is connected through a conductor 29, contained within a support cable 14, to the power source T_1. The coil 30 is connected to the power source T_2 through a conductor 31, also contained within the support cable 14. The bird 12 has an outer structure of non-conducting or slightly conducting material, such as a plastic material, and the transmitter coils 28 and 30 are encased in a solid plastic nose or end section 32 to ensure a constant positional relationship between these transmitter coils. In the rearward section 34 of the bird 12, which is plastic, receiver coils 36 and 38 are located and are shown perpendicularly or orthogonally oriented with respect to each other. Here again, the coils are encased in a solid plastic block or section 39 to ensure a constant positional relationship between the receiver coils. Sections 32 and 34 of the bird are rigidly connected by a tubular section which is provided with internal braces 40 as shown in Figure 2 to ensure a substantially constant positional relationship between the transmitter and receiver coils. The receiver coil 36 is located in the same plane as the transmitter coil 28 and the receiver coil 38 is located in a plane parallel to that of the transmitter coil 30. Amplifiers A_1 and A_2 are located within the bird 12 and are electrically connected to the receiving coils 36 and 38, respectively, although the signals from the two receiver coils may if desired be fed to a single amplifier. The outputs of amplifiers A_1 and A_2 are connected to a modulator 44, also located within the bird. The output of the modulator 44 is connected through a conductor 45 contained within the supporting cable 16 to a detector 26 located within the aircraft. The output of the detector 26 is connected to a suitable recorder 24.

The power source T_1 and the amplifier A_1 are tuned to one frequency while power source T_2 and amplifier A_2 are tuned to another frequency. These frequencies are within the range of near zero to about 20,000 cycles per second and are selected to minimise the modulation effect of helicopter rotors and any effect of mechanical vibrations which may develop within the system. The following points should be considered when frequencies are selected:—

1. A low frequency is best for good sulphide conductors.
2. The lower the frequency the larger the equipment and the more weight that must be carried.
3. Separation of the two frequencies must be sufficient for satisfactory filtering one from the other.
4. One frequency is preferably not a harmonic of the other.
5. Rotor modulation, assuming a four bladed rotor turning at 600 r.p.m. = 2400/60 = 40 c.p.s.
6. Mechanical resonances are avoided by design of the structure to lie outside the detecting frequency stage.

The rate of increase and decrease of the response from the ore body can be controlled to some extent by the choice of altitude and the forward speed of the helicopter, which can assist in filtering out any spurious signals. Certain extraneous or random noises have been found to fall within a fixed frequency range. To distinguish the response from a conductive body from these extraneous or random noises, the aircraft should be flown at such a speed as will make all responses from conductive bodies have a different frequency. Thus, for example, the random noises may have a frequency of from about one to five seconds. Then the responses from conductive bodies can be distinguished from these random noises if the aircraft is flown at a sufficiently low speed to make all responses from conductive bodies have a frequency greater than this 5 second maximum of the random noises.

The operation of the system is as follows: The helicopter or other aircraft is guided over the terrain to be surveyed and energy is radiated from the transmitting system including the transmitter coils 28 and 30 transmitting in mutually perpendicular planes at selected frequencies, preferably in the range of up to about 5,000 cycles per second. The corresponding electromagnetic fields are various affected by mineral bodies in the terrain. The responses due to various bodies are received by the receiving coils 36 and 38 and their associated amplifiers or receivers A_1 and A_2. These responses are combined and transmitted by the modulator 44 to the detector 26 which, in turn, delivers an appropriate signal to the recorder 24, thereby providing indication and measurement of the presence of the mineral body.

This invention is particularly useful at low altitudes and low air speeds and thus markedly increases the resolving power of the equipment and decreases the power requirements. Since the aircraft can move slowly or even hover over a particular area, precise measurements and locations of the mineral ore bodies become possible.

A great advantage over the generally known methods is obtained by use of the present invention in that spurious signals, such as those that may be picked up by or caused in the supporting cables are greatly reduced, due to the impression of the received signals on a carrier wave in the modulator and the transmission of the modulated wave to the detector 26 wherein the responses to the one or more electromagnetic fields are detected and separated from the carrier wave.

The electromagnetic equipment and its operation may be similar to that disclosed in our Application No. 33633/58 (Serial No. 899,607), which relates to the use of a special combination of a plurality of transmitter coils for radiating at least three electromagnetic fields of different frequencies, and a receiving system for receiving the responses due to the three fields and comparing them to indicate and measure various bodies. The electromagnetic equipment and its operation may also employ mutually orthogonal transmitter coils to radiate two frequency distinguished electromagnetic fields, and a second pair of mutually orthogonal coils to receive the responses from these coils due to the presence of various conductive bodies. The received signals are combined and amplified by a common amplifier, then separated by filters into the two frequencies and the two frequencies finally combined to indicate the conductive bodies.

WHAT WE CLAIM IS:—

1. A method of making a record of responses received from earth formations detected and measured by airborne electromagnetic operations which comprises radiating two electromagnetic fields from a transmitting coil system carried by a bird which is towed from an aircraft by one or more cables, receiving the electromagnetic field responses due to earth formations by a receiving coil system in the bird, impressing the received response on an electrical carrier wave, transmitting the modulated electrical carrier wave along the or one of the cables, detecting and separating the responses due to earth formations from the

electrical carrier wave, so that the earth formations are indicated and measured.

2. A method of making a recording of responses received from earth formations detected and measured by airborne electromagnetic operations, according to Claim 1 and substantially as described with reference to the accompanying drawings.

3. An electromagnetic device for detecting and measuring an ore body comprising, in combination with an aircraft and a bird suspended beneath the aircraft, two transmitting coils carried by the bird, a first and a second power source carried by the aircraft and each tuned to a different frequency and each connected to a separate one of the transmitting coils, two receiving coils carried by the bird spaced from the transmitting coils and each tuned to a different one of the frequencies and a modulator located in the bird and connected to the first and second receiving coils, and means for detecting and comparing the signals received by the receiving coils.

4. A device according to Claim 3 in which the aircraft is a helicopter.

5. A device according to Claim 3 in which the transmitting coils are rigidly mounted and oriented perpendicular to each other.

6. A device according to Claim 5 in which the receiving coils are rigidly mounted, one of the receiving coils being in substantially the same plane as one of the transmitting coils and the other of the receiving coils being in a plane substantially parallel to the plane of the other transmitting coil.

7. A device according to Claim 6 in which the transmitting coils are embedded in a plastic section of the forward end of the bird.

8. A device according to Claim 7 in which the receiving coils are embedded in a plastic section of the rearward end of the bird.

9. A device according to Claim 6 in which the means for receiving and comparing the received signals include a first amplifier connected to one of the receiving coils and a second amplifier connected to the other receiving coil and a modulator located in the bird and connected to the first and second amplifiers.

10. An electromagnetic device according to Claim 3 substantially as described with reference to the accompanying drawings.

For the Applicants:—
GILL, JENNINGS & EVERY,
Chartered Patent Agents,
51/52 Chancery Lane,
London, W.C.2.

Abingdon: Printed for Her Majesty's Stationery Office, by Burgess & Son (Abingdon), Ltd.—1962.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2.
from which copies may be obtained.

899,606 COMPLETE SPECIFICATION
1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

FIG. 1.

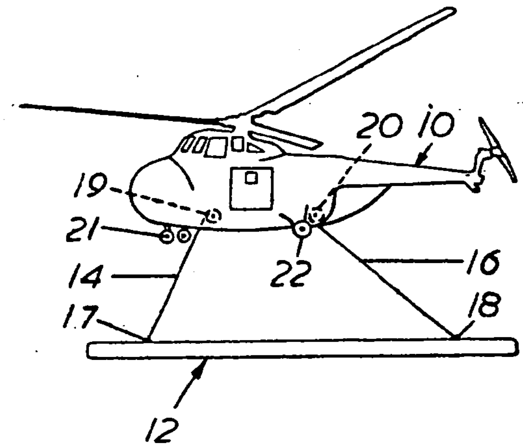

FIG. 2.